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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H04B 7/06 — A1

(11) International Publication Number: **WO 00/51265**

(43) International Publication Date: 31 August 2000 (31.08.00)

(21) International Application Number: PCT/US00/02958

(22) International Filing Date: 4 February 2000 (04.02.00)

(30) Priority Data:
09/253,786 22 February 1999 (22.02.99) US

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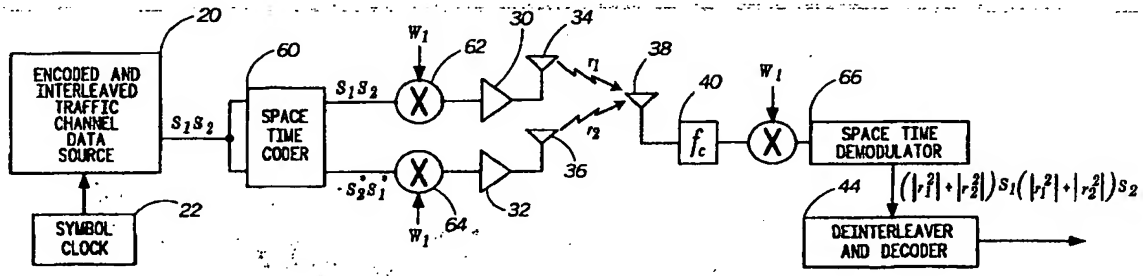
(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KG, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: METHOD AND SYSTEM USING TRANSMIT DIVERSITY TECHNIQUES



(57) Abstract

In a method for wireless data communication between a transmitter and a receiver in a wireless communication system, groups of symbols of an input data stream are commutated (24) to produce a plurality of commutated data streams. The plurality of commutated data streams are then transformed to produce a plurality of transformed data streams. Next, each transformed data stream is spread (26, 28) with a selected one of a plurality of spreading codes to produce a plurality of antenna signals. Finally, each of the plurality of antenna signals is transmitted using a selected one of a plurality of spaced apart antennas (34, 36), wherein the plurality of spaced apart antennas (34, 36) are spaced apart to provide transmit diversity. In one embodiment, the transform is a space–time transform.

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METHOD AND SYSTEM USING TRANSMIT DIVERSITY TECHNIQUES

Field of the Invention

The present invention is related in general to wireless communications systems, and more particularly to an improved method and system for transmitting and demodulating a communications signal that has been transmitted from an antenna array using a new combination of transmit diversity techniques.

Background of the Invention

An important goal in designing a wireless communication system is to increase the number of users that may be simultaneously served by the communication system. This goal may be referred to as increasing system capacity. In an interference limited system, such as a code division multiple access (CDMA) wireless communications system, one way to increase capacity is by lowering the transmit power allocated to each user. By lowering the allocated transmit power, interference for all users is lowered, which provides additional capacity which may be used to add new users.

One way to lower the transmit power for each user is to increase the efficiency of the wireless link or channel between the user or subscriber unit and the base station that serves that user. One phenomena that reduces the efficiency of the communications link is fading. Fading may take several forms, one of which is referred to as multi-path fading. Multipath fading is caused by two or more copies of a transmitted signal combining at the receiver in a way that reduces the overall received signal level.

In the prior art, several diversity techniques have been proposed for reducing the effects of fading. These techniques include orthogonal transmit diversity (OTD) and space-time transmit diversity (STTD).

With reference now to **FIG. 1**, there is depicted a high-level block diagram of a transmitter and receiver for implementing an orthogonal transmit diversity

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system. As illustrated, data source **20** provides a stream of symbols, which may be encoded and interleaved. Such symbols may represent data in one or more traffic channels which are to be transmitted to the subscriber unit. Data in the traffic channels may represent voice, data, video, or other data a user desires to transport via the communication system.

The rate that symbols are output from data source **20** is controlled by symbol clock **22**. Symbols S_1 and S_2 are shown coming from data source **20** wherein each symbol is output for 1 period of symbol clock **22**, or a symbol period which may be described as the duration from T_0 to T_1.

The serial stream of symbols from data source **20** is coupled to commutator **24**, which switches at the rate of symbol clock **22**. Commutator **24** sends the first symbol to spreader **26**, then switches to send the second symbol, S_2, to spreader **28**. Subsequent symbols alternate each symbol period between spreader **26** and **28**.

Spreaders **26** and **28** spread the symbols by multiplying them by a spreading code, such as a Walsh code. Because the symbol rate at spreaders **26** and **28** is half the rate that symbols are sourced from data source **20**, a single Walsh code may be concatenated to form a new Walsh code at spreader **26**, and concatenated with an inverted copy to form the spreading code at spreader **28**. With these double-length Walsh codes used to spread half-rate symbols, the chip rate output by spreaders **26** and **28** remains the same as a transmission without OTD.

The outputs of spreaders **26** and **28** are coupled to radio frequency transmitters **30** and **32**. These radio frequency transmitters may include a modulator, followed by an up converter for up converting the modulated signal to a selected carrier frequency, and an amplifier for providing suitable power for transmitting the radio frequency signal.

The outputs of radio frequency transmitters **30** and **32** are coupled to antennas **34** and **36** for simultaneously transmitting symbols S_1 and S_2. Because

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antennas 34 and 36 are spaced apart, the characteristics of the various paths or rays that the signals follow from each antenna to the subscriber unit may be measured separately, and described by coefficients shown as r_1 and r_2, where r_1 and r_2 are complex numbers that represent the gain and phase of the channel. Although r_1 and r_2 are treated here as single values, they may be vectors which describe the gain and phase of a plurality of resolvable multipath rays.

Antenna 38 is used by the subscriber unit to receive signals transmitted from antennas 34 and 36. The received signal is down converted an demodulated in down converter and demodulator 40 and decoded in OTD decoder 42.

The output of OTD decoder 42 is recovered symbols multiplied by the square of the magnitude of the channel coefficients r_1 and r_2, respectively. Further details of the operation of OTD decoder 42 are shown in **FIG. 2**, which is discussed below.

The OTD decoder outputs are coupled to deinterleaver and decoder 44 for the deinterleaving and decoding processes that corresponds to the encoding and interleaving processes performed in data source 20. The output of deinterleaver and decoder 44 is the traffic channel data. Transmit power is reduced for the same quality of service with the OTD diversity technique because different symbols experience different channel gains. This lowers the likelihood that both symbols will simultaneously experience a deep fade. This statistical unlikelihood that both symbols will be faded improves the decoder performance.

With reference now to **FIG. 2** there is depicted a schematic representation of OTD decoder 42, which is used in **FIG. 1**. The input to OTD decoder 42 is a down-converted received signal, which was received from antenna 38. This signal contains traffic channels for all users along with pilot signals that may be used to estimate the channels from each transmit antenna. Channel estimator 50 evaluates the pilot signals and calculates channel coefficients r_1 and r_2.

In a preferred embodiment, despreaders 52 and 54 despread the received signal using a single Walsh code that has been concatenated, as in the transmitter,

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in order to recover symbols S_1 and S_2. Multipliers **56** and **58** multiply these recovered symbols by the conjugate of the channel estimates in order to compensate for gain and phase changes that occurred in the channel. Decommutator **59** is used to restore the symbol order and thereby double the symbol rate of the outputs from multipliers **56** and **58**. The outputs of OTD decoder **42** are the symbols multiplied by the magnitude of the respective channel estimate squared.

With reference now to **FIG. 3**, there is depicted another method and system for providing transmit diversity. **FIG. 3** illustrates a space-time transmit diversity transmitter and receiver. As illustrated, data source **20** and symbol clock **22** provide symbols S_1 and S_2 to space-time coder **60**. At the input, S_1 is received by space-time coder **60** during the period from T_0 to T_1. Symbol S_2 is received at the input of space-time coder **60** during the period from T_1 to T_2. Space-time coder **60**, which is a special type of transform operation, has two outputs that provide transform signals to two branches of the transmitter.

At the first output of space-time coder **60**, symbol S_1 is output during the symbol time from T_0 to T_1, followed by symbol S_2 from symbol time T_1 to T_2. The second output of space-time coder **60** outputs the negative complex conjugate of symbol S_2 during time T_0 to T_1, followed by the complex conjugate of symbol S_1 from the period T_1 to T_2.

The first and second space-time encoded data streams output by space-time coder **60** are then input into spreaders **62** and **64**. As shown, spreaders **62** and **64** use Walsh code W_1. Note that the chip rate per symbol remains the same as in the OTD diversity transmitter.

Following the spreading function at spreaders **62** and **64**, the spread data streams are modulated, up converted, and amplified by radio frequency transmitters **30** and **32**.

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The outputs of radio frequency transmitters **30** and **32** are coupled to antennas **34** and **36**, which transmit the signals via channels that may be described with channel coefficients r_1 and r_2.

In the subscriber unit, antenna **38** receives the transmitted signals. The transmitted signals are then down converted using down converter and demodulator **40** and coupled to despreader **41**, and thereafter to space-time decoder **66**. The output of space-time decoder **66** is the estimated symbols multiplied by a factor calculated from the sum of the squares of the magnitude of the channel coefficients. These symbols and factors are then input into deinterleaver and decoder **44**, which deinterleaves and decodes the symbols and outputs traffic channel data.

Although deinterleaver and decoder **44** are shown with the same reference numeral in **FIG. 1** and **FIG. 3** for both the OTD and STTD diversity schemes, respectively, it is important to understand that the deinterleaver and decoder function corresponds to the encoding and interleaving processes used in data source **20**. Some performance improvements may be realized by selecting interleaving schemes specifically for a particular one of the diversity techniques. The reason that a different interleaving function provides a different result is that the OTD diversity scheme uses commutator **24**. The interleaving scheme for OTD should be selected so that adjacent symbols experience different fading through different channels.

With reference now to **FIG. 4**, there is depicted a high-level schematic diagram of a space-time decoder, as used in **FIG. 3** at reference numeral **66**.

The input to space-time decoder **66** is a down converted and despread received signal that was received from antenna **38**. This signal contains traffic channel data for all users along with pilot signals that may be used to estimate the channels from each transmit antenna. Channel estimator **50** evaluates these pilot signals and calculates channel coefficients r_1 and r_2.

Complex conjugators **70** are used as shown to compute the complex conjugate of the down converted and despread signal, and compute the conjugate

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of channel coefficient r_1 for input to multipliers 72. Multipliers 72 are used to multiply the received signal, or the complex conjugate of the received signal, by channel coefficients r_2, or the complex conjugate of channel coefficients r_1. Adders 74 are used to add the output signals from multipliers 72 to produce signals that represent a symbol multiplied by a factor computed from both channel coefficients. These weighted symbols are then decommutated by decommutator 76 to produce the sequential output of the weighted symbols.

Note that signals labeled $x_1(t)$ are different—they are derived from the signal x(t) at two different times, the times of two sequential symbols periods.

The two methods that are described above for providing transmit diversity use two antennas. Additional transmit diversity may be obtained by increasing the number of antennas. The orthogonal transmit diversity method may be easily implemented with more than two antennas, however merely adding antennas does not increase performance as much as other methods with the same number of antennas.

With regard to the transmitter that uses space-time transmit diversity, this technique is not easily expanded beyond two antennas without using additional system resources, such as Walsh codes or increasing the coding rate, which results in any gain in diversity being cancelled by the loss of capacity.

Therefore, it should be apparent that there is a need for an improved method and system for transmitting and receiving signals transmitted from an antenna array with transmit diversity techniques.

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Brief Description of the Drawings

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objects, and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

FIG. 1 depicts a high-level block diagram illustrating a transmitter and receiver for implementing orthogonal transmit diversity;

FIG. 2 depicts a schematic representation of orthogonal transmit diversity decoder, as shown in **FIG. 1**;

FIG. 3 depicts a space-time transmit diversity method and system for providing transmit diversity;

FIG. 4 depicts a high-level schematic diagram of a space-time decoder, as shown in **FIG. 3**;

FIG. 5 depicts a system for transmitting signals from an antenna array using a transmit diversity technique in accordance with the method and system of the present invention;

FIG. 6 depicts a high-level logic flowchart illustrating the method and operation of the transmitter depicted in **Fig. 5** according to the method and system of the present invention;

FIG. 7 depicts a subscriber unit for receiving and demodulating a signal transmitted by the transmitter of **FIG. 5**;

FIG. 8 depicts a high-level logic flowchart illustrating the method and operation of the subscriber unit shown in **FIG. 7** in accordance with the method and system of the present invention;

FIG. 9 depicts an alternative embodiment of a transmitter in accordance with the method and system of the present invention;

FIG. 10 depicts another embodiment of a transmitter having selected antenna outputs;

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FIG. 11 depicts a receiver which may be used in a subscriber unit to receive signals transmitted by the transmitter shown in FIG. 10;

FIG. 12 depicts a transmitter for providing signals with transmit diversity;

FIG. 13 depicts a high-level logic flowchart illustrating the method and system operation of the transmitter shown in FIG. 12;

FIG. 14 depicts a receiver for receiving and demodulating the signals transmitted with transmit diversity from the transmitter shown in FIG. 12;

FIG. 15 depicts a high-level logic flowchart that shows the method and operation of the diversity receiver shown in FIG. 14; and

FIG. 16 depicts a transmitter for transmitting diversity signals that has antenna selection.

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Detailed Description of the Invention

With reference now to **FIG. 5**, there is depicted a system for transmitting signals from an antenna array using a transmit diversity technique in accordance with the method and system of the present invention. As shown, data source **20** provides a data stream of symbols, which may be encoded and interleaved. These symbols, shown as S_1 through S_4, are output at a rate determined by symbol clock **22**.

The output of data source **20** is coupled to commutator **80**, which, in this example, selects pairs of symbols that are output along branches **82** and **84** of the transmitter. Note that commutator **80** operates at one half of the rate of symbol clock **22**, as shown by the output from divider **86**. This means that the data rates along branches **82** and **84** are half the rate output from data source **20**. Divider **86** divides by two because two symbols are selected for each branch. If any other number of symbols were selected for each branch, divider **86** would divide by the number of symbols selected.

Transformers **88** and **90** are coupled to the data streams output from commutator **80**. Transformers **88** and **90** transform the pairs of symbols to produce two data streams that represent different mathematical combinations of the group of symbols that was input into the transformer. The groups of symbols are transformed, or combined mathematically, in such a way that they may be mathematically separated in the receiver using the measured channel coefficients.

In a preferred embodiment, transformers **88** and **90** are implemented with space-time coders, such as a space-time coder **60** described with reference to **FIG. 3**. In the example shown in **FIG. 5**, space-time coders **88** and **90** each output first and second space-time encoded data streams, which are then coupled to the input of spreaders **92** in branch **82** and spreaders **94** in branch **84**. Spreaders **92** use the same spreading code, which is shown in **FIG. 5** as the concatenation of W_1 with W_1. Spreaders **94** use another spreading code formed by concatenating W_1 with the inverse of W_1. The spreading codes selected for spreaders **92** and spreaders **94**

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are orthogonal to one another in the sense the signals in branches **82** and **84** may be separated from one another at the receiver.

The output of spreaders **92** and spreaders **94**, which may be referred to as antenna data streams, are then modulated, up converted, amplified, and transmitted from a selected antenna element in an antenna array. The modulation and up conversion function are shown in **FIG. 5** at modulator and up converters **96**. Amplification is performed by amplifiers **98**, which are coupled to antennas **100** through **106**.

Referring now to **FIG. 6**, there is depicted a high-level logic flowchart that illustrates the method and operation of the transmitter depicted in **Fig. 5** according to the method and system of the present invention. As shown, the process starts at block **300** and thereafter passes to block **302** wherein the process commutates groups of symbols of an input data stream to produce a plurality of commutated data streams. This step may be implemented as shown in **FIG. 5** with commutator **80** that commutates pairs of symbols to produce a plurality of commutated data streams, which are then input into space-time coders **88** and **90**. Next, the process transforms each group of symbols in each of the plurality of commutated data streams to produce first and second transformed data streams, as illustrated at block **304**. In a preferred embodiment, and as shown in **FIG. 5**, this transforming step may be implemented using space-time coders, such as space-time coders **88** and **90**.

This transform operation may be represented mathematically as described below. The input vector is

$$X=[S_1, S_2]$$

Where S_1 and S_2 are the (complex-valued) input symbols. The corresponding output vector is

$$Y=[Y_1, Y_2]$$

Where $Y_1 = [S_1, -S_2^*]^T$, $Y_2 = [S_2, S_1^*]^T$, $[.]^T$ represents vector transpose operation, and $[.]^*$ denotes conjugation.

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This transform is characterized by the fact that the commutated data streams input into the transformers may be recovered at the subscriber unit after passing through the radio frequency channel.

After transforming each commutated data stream, the process spreads each pair of first and second transformed data streams with a spreading code to produce antenna data streams, as depicted at block **306**. In this spreading operation, the plurality of transformed data streams output by a single transformer are each spread with the same spreading code. Transformed data streams output by different transformers are spread with different spreading codes. This step is illustrated in **FIG. 5** wherein the outputs from space-time coder **88** are both spread with the same spreading code at spreaders **92**, while the outputs from space-time coder **90** are spread with another spreading code at spreaders **94**.

Finally, each antenna data stream is modulated, up converted, amplified, and transmitted from a selected antenna element in an antenna array, as illustrated at block **308**. This step is shown in **FIG. 5** wherein modulator and up converters **96** represent the modulation and up-conversion steps. Amplifiers **98** increase the power of the signals so that they may be transmitted by antennas **100** through **106**. As discussed later, pilot signals are added in the transmitter so that channel measurements can be made.

Referring now to **FIG. 7**, there is depicted a subscriber unit for receiving and demodulating a signal transmitted by the transmitter of **FIG. 5**. As illustrated, antenna **120** receives signals transmitted from antennas **100** through **106** (see **FIG. 5**), wherein each signal has traveled through a path or channel that may be described by channel coefficients r_1 through r_4. Signals from antenna **120** are coupled to down converter and demodulator **122**, which removes the carrier from the signals and produces a baseband received signal.

The baseband received signal is coupled to the inputs of despreaders **124** and **126**, which remove the spreading codes that were used at spreaders **92** and **94** in **FIG. 5**. These despreaders **124** and **126** are used to separate the baseband

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received signal into two signals that correspond to the signals in branches **82** and **84** of **FIG. 5**. The outputs of despreaders **124** and **126** are despread baseband received signals.

The despread baseband received signals are then coupled to inverse transformers **128** and **130**. In a preferred embodiment, inverse transformers are implemented with STTD decoders, as shown in **FIG. 4**. However, in each embodiment of the invention, inverse transformers **128** and **130** perform the inverse operation of the operation performed in transformers **88** and **90** in **FIG. 5**. This inverse transform ideally has zero inter-symbol interference, however some transform operations may have some minimal residual inter-symbol interference.

In the preferred embodiment using the STTD decoder, the inverse transform mathematical operation may be described by the equation below. The received signals at two consecutive symbol periods are

$X_1 = r_1 S_1 - r_2 S_2^*$ and $X_2 = r_1 S_2 + r_2 S_1^*$

Thus, transmitted symbols can be recovered as follows:

$S_1 = r_1^* X_1 + r_2 X_2^*$ and $S_2 = r_1^* X_2 - r_2 X_1^*$

Outputs from inverse transformers **128** and **130** are coupled to de-commutator **132**, which reorders the symbols output by inverse transformers **128** and **130** to produce the original symbol order at the original symbol rate output by data source **20** (see **FIG. 5**). Note that in the example shown in **FIG. 7**, de-commutator **132** operates at one half the symbol rate to produce an output at the full symbol rate. If symbols are grouped in groups larger than pairs of symbols, de-commutator **132** would operate at the symbol rate divided by the number of symbols in a group.

The output of de-commutator **132** is coupled to deinterleaver and decoder **134**. Deinterleaver and decoder **134** deinterleaves and decodes the symbols in operations that match the interleaving and encoding methods used in data source **20** (see **FIG. 5**). The output of deinterleaver and decoder **134** is a symbol data stream representing the traffic channel data.

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Two type of gains may be realized from the architecture shown in **FIG. 7**. One type of gain is a path gain, which is realized because paths r_1 and r_2 are combined in a coherent way, as shown by the factors in the outputs from inverse transformers **128** and **130**. Additionally, decoding gain may be realized because the circuit in **FIG. 7** has multiple branches, wherein the branches are distinguished by a despreader coupled to an inverse transformer. The signals processed in these branches have traveled through different paths, which makes it statistically less likely that the signals on both of the branches will experience a deep fade at the same time.

Referring now to **FIG. 8**, there is depicted a high-level logic flowchart that illustrates the method and operation of the subscriber unit shown in **FIG. 7** in accordance with the method and system of the present invention. As illustrated, the process begins at block **320** and thereafter passes to block **322** wherein the process receives and down-converts a received signal to produce a baseband received signal. This step may be implemented with down converter and demodulator **122**, as shown in **FIG. 7**.

Next, the process despreads the baseband received signal using a plurality of Walsh codes that correspond to the Walsh codes used in the transmitter for producing the antenna data streams, as illustrated at block **324**. The output of the despreaders are referred to as received transformed signals, and the despreading operation is shown in **FIG. 7** at despreaders **124** and **126**.

The process next inverse transforms each received transformed signal using a plurality of inverse transformers to produce inverse transformer output signals, as depicted at block **326**. In a preferred embodiment, this step is implemented with STTD decoders coupled to the outputs of each despreader **124** and **126** (see **FIG. 7**). The mathematical operation performed in inverse transformers **128** and **130** is discussed with reference to **FIG. 7**.

Next, the inverse transformer output signals are decommutated to produce an interleaved encoded signal, as illustrated at block **328**. This step is performed by de-commutator **132**, as shown in **FIG. 7**.

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Finally, the interleaved encoded signal is deinterleaved and decoded to produce the traffic channel data signal, as depicted at block **330**. The de-interleaving and decoding process compliments the encoding and interleaving process that may have been performed on the input data stream provided by data source **20** (see **FIG. 5**). Following block **330**, the process iteratively returns to block **322**, wherein a new signal is received and demodulated and decoded in a similar manner.

With reference now to **FIG. 9**, there is depicted an alternative embodiment of a transmitter in accordance with the method and system of the present invention. The transmitter shown in **FIG. 9** is similar to the transmitter shown in **FIG. 5**, and similar portions of the schematic are shown with the same reference numerals. The performance of the transmitter in **FIG. 9** is further improved by the addition of antenna selector **140**, which is coupled between amplifiers **98** and antennas **100** through **106**. Antenna selector **140** may couple the output of any amplifier **98** to any antenna **100** through **106**. Preferably, the output of each amplifier **98** is coupled exclusively to one of the antennas at any given time.

In a preferred embodiment, antenna signals **142-148** are coupled to selected antennas by antenna selector **140** in a switching pattern shown in the table below.

Time Period	Signal 142	Signals 144	Signal 146	Signal 148
0 T_x	A_1	A_2	A_3	A_4
T_x $2T_x$	A_1	A_3	A_2	A_4
$2T_x$ $3T_x$	A_1	A_4	A_2	A_3

The switching pattern may be stored in switching pattern generator **150**, which is coupled to antenna selector **140**. While the antenna switching pattern shown in Table 1 is a periodic switching pattern with three states, other methods of switching with a larger number of states is possible. For example, instead of periodic switching, random switching may be used. Whatever pattern and timing of switching is selected, knowledge of this switching pattern is required in the subscriber unit so that the proper channel coefficients may be multiplied by the proper symbols in the symbol demodulator.

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The rate at which antenna selector **140** changes is synchronized with symbol clock **22** and determined by the output of divider **152**. Thus, the antenna switching rate is slower than the symbol rate.

The subscriber unit used to receive signals transmitted by the transmitter of **FIG. 9** is similar to the receiver architecture shown in **FIG. 7**. However, in order to receive a signal that uses antenna switching as shown in **FIG. 9**, each inverse transformer must include a channel estimator that can select the proper channel to estimate based on the antennas selected at the transmitter. In a preferred embodiment, the inverse transformer is a space-time decoder, such as space-time decoder **66** shown in **FIG. 4**. When antenna signals **142** and **144** are coupled to antennas A_1 and A_2, respectively, channel estimator **50** estimates channel coefficients r_1 and r_2. For antenna signals **146** and **148**, channel estimator **50** in space-time decoder **66** would estimate channel coefficients r_3 and r_4. As new combinations of antennas are selected by antenna selector **140**, channel estimator **50** may estimate, for example, r_1 and r_3. It is important that channel estimator **50** in space-time decoder **66** estimate channel coefficients for the channels used by one of the transformers in the transmitter. Optional switching pattern generator **154** is shown in space-time decoder **56** (See **FIG. 4**) for the purpose of selecting the proper channel coefficients.

With reference now to **FIG. 10** there is depicted yet another embodiment of a transmitter having switched or selected antenna outputs. The transmitter depicted in **FIG. 10** is similar to that depicted in **FIG. 9**, however antenna selector **160** is coupled to only three antennas, antennas **100** through **104**. Because antenna selector **160** is connected to only three antennas, switching pattern generator **162** must accommodate a switching pattern which maps four antenna signals **142-148** into three antennas **100** through **104**. In this embodiment, more than one antenna signal is mapped to a selected antenna.

Referring now to **FIG. 11**, there is depicted a receiver which may be used in a subscriber unit to receive signals transmitted by the transmitter shown in **FIG. 10**. As shown, antenna **120** receives signals transmitted from antennas **100**

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through **104** (see **FIG. 10**) and couples the received signals to down converter and demodulator **122**. The output of down converter and demodulator **122** is a baseband received signal.

The baseband received signal is coupled to despreaders **124** and **126**, wherein the baseband signal is despread using two different despreading codes, as shown. The two despreading codes correspond to spreading codes used by spreaders **92** and **94** in the transmitter shown in **FIG. 10**.

The outputs of despreaders **124** and **126**, which may be referred to as despread baseband received signals, are coupled to inverse transformers **172**, respectively. Inverse transformers **172** perform the inverse operation of that performed in transformers **88** and **90** (see **FIG. 10**) except that inverse transformers **172** have specific knowledge of the switching pattern used in antenna selector **160** so that it may calculate the proper channel coefficients. This switching pattern is provided to inverse transformers **172** by switching pattern generator **174**. Switching pattern generator produces a pattern similar to that produced in switching pattern generator **162** in the transmitter of **FIG. 10**.

The inverse transformer output signals are coupled to de-commutator **132** which reorders the channel detected symbols from the two branches of the receiver. In this example, where symbols are grouped in pairs, the clock in de-commutator **132** runs at one half the symbol rate. The output of de-commutator **132** is an interleaved encoded signal.

The interleaved encoded signal is input into deinterleaver and decoder **134**, which deinterleaves and decodes the symbols according the appropriate de-interleaving and decoding schemes that compliment the schemes used in data source **20**.

The coefficients shown in **FIG. 11** at the outputs of inverse transformers **172** represent the signals output when antenna signal **142** is coupled to antenna **100**, antenna signal **144** is coupled to antenna **102**, antenna signal **146** is coupled to antenna **104**, and antenna signal **148** is coupled to antenna **100**.

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With reference now to **FIG. 12**, there is depicted a transmitter for providing signals with transmit diversity. As shown, data source **20** provides an encoded and interleaved traffic channel data source, of which two symbols are shown as symbols S_1 and S_2. The rate of the output from data source **20** is controlled by symbol clock **22**. The output of data source **20** is coupled to the input of transformer **88** which transforms groups of symbols to produce a plurality of transformed data streams as an output. In a preferred embodiment, transformer **88** may be implemented with a space-time coder, similar to the space-time coder discussed above with reference to **FIG. 3**.

The plurality of transformed data streams output by transformer **88** are coupled to a plurality of spreaders, shown in **FIG. 12** as spreaders **92**. In the transmitter shown in **FIG. 12**, the outputs of transformer **88** are spread with the same spreading code.

The output of spreaders **92** may be referred to as antenna data streams because they are ready for modulation, up conversion, amplifying, and transmitting via an antenna. In the example shown in **FIG. 12**, these antenna data streams are input into commutator **170**, which commutates the signal at a divided symbol clock rate determined by divider **152**. In this example, commutator **170** switches antenna data streams between two different paths selected for each data stream, which produces four commutated antenna data streams.

In a preferred embodiment, the switches in commutator **170** select an output for a period of two symbol times. Other clock rates may be used, wherein the clock has a period of N times the number of symbols in a group, times the symbol time.

The outputs of commutator **170** are coupled to a selected modulator and up converter **96**, which modulates the signal and up converts the signal to the carrier frequency. Note that when an output of commutator **170** is not connected to modulator and up converter **96**, the input to that modulator and up converter is set to zero.

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Outputs from modulator and up converter **96** are coupled to inputs of a hybrid matrix amplifier **180** for amplifying the signals so that they may be transmitted from antennas **100** through **106**. Hybrid matrix amplifier **180** includes transformer **182** having outputs coupled to amplifiers **98**. Each amplifier **98** has an output coupled to an input of an inverse transformer **184**, which performs a complimentary transform to the transform performed in transformer **182**. Transformer **182** and inverse transformer **184** are preferably implemented with fourier matrix transformers. The advantage of using hybrid matrix amplifier **180** is that all amplifiers **98** equally share the power amplifying function, even when some inputs to hybrid matrix amplifier **180** are set to zero.

The outputs of hybrid matrix amplifier **180** are coupled to antennas **100** through **106** for transmitting signals over various channels with transmit diversity.

Referring now to **FIG. 13**, there is depicted a high-level logic flowchart which illustrates the method and system operation of the transmitter shown in **FIG. 12**. As illustrated, the process begins at block **340** and thereafter passes to block **342** wherein the process transforms groups of symbols from the input data stream to produce a plurality of transformed data streams. This step may be performed as shown in **FIG. 12** with transformer **88**. In a preferred embodiment, the transformer is a space-time transformation that produces first and second transformed data streams, as discussed above with reference to **FIG. 3**.

Next, the process spreads the first and second transformed data streams with a spreading code to produce first and second spread data streams, as illustrated at block **344**. This step may be implemented with spreaders, as shown in **FIG. 12** at reference numerals **92**.

Next, the process determines whether or not the present group is an even group of symbols, as depicted at block **346**. Note that in the present example, commutator **170** has two states which may be referred to as an even state and an odd state. If commutator **170** had more than two states, the process would

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determine the current state of the N states at block **346**. The present example is simplified by using only two states.

If the process determines that the present group is an even group, the process selects the even amplifier inputs, as depicted at block **348**. However, if the process determines that the present group is an odd group, the process selects the odd amplifier inputs, as illustrated at block **350**.

Following the selection of the amplifier inputs, the process couples each pair of symbols represented in the first and second spread data streams to a pair of amplifier inputs, wherein the amplifier inputs correspond to pair of a selected elements in an antenna array, as depicted at block **346**. This step is implemented using a commutator, such as commutator **170** shown in **FIG. 12**. Thus, the commutator connects a pair of a transformed and spread symbols from the outputs of spreaders **92** to a pair of inputs of an amplifier array, or hybrid matrix amplifier.

After the amplifier inputs have been selected and coupled, the process modulates, up converts, amplifies, and transmits the first and second spread data streams using the selected elements of the antenna array, as depicted at block **354**. Note that in a preferred embodiment of the present invention, these signals are amplified using a hybrid matrix amplifier, as shown in **FIG. 12** at reference numeral **180**. The hybrid matrix amplifier is selected because it reduces the peak-to-average value of the signals experienced by each amplifier in the hybrid matrix amplifier array.

Note that while modulator and up converters **96** are shown at the outputs of commutator **170**, a pair of modulator and up converters **96** may be used prior to the input of commutator **170**.

Following block **354**, the process iteratively returns to block **342** to process the next group of symbols.

With reference now to **FIG. 14**, there is depicted a receiver for receiving and demodulating the signals transmitted with transmit diversity from the transmitter shown in **FIG. 12**. As illustrated, antenna **120** receives signals via channels that

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may be described with channel coefficients r_1 through r_4. These signals are coupled to down converter and demodulator **122**, which down converts and demodulates the signals to produce a baseband received signal.

The baseband received signal is input into despreader **124** which despreads and produces a despread baseband received signal. Despreader **124** uses a despreading code similar to the spreading code used in spreaders **92** in **FIG. 12**.

The despread baseband received signal is input into inverse transformer **128**, which provides an inverse transform function similar to that discussed with reference to **FIG. 4**. The output of inverse transformer **128** is symbols S_1 and S_2 multiplied by coherently combined channel gains. The outputs shown in **FIG. 14** occupies two symbol times. In the next two symbol times, as a result of antenna switching at commutator **170**, the symbols will travel through different channels, which may be described by channel coefficients r_3 and r_4. Receiving different symbols through different channels provides interleaving gain. Receiving the same symbol through multiple channels provides path diversity gain.

In a preferred embodiment, inverse transformer **128** may be implemented with a space-time decoder, similar to that shown in **FIG. 4**.

The output of inverse transformer **128** is coupled to deinterleaver and decoder **134**. Deinterleaver and decoder **134** deinterleaves and decodes the received symbols in a manner suitable for recovering traffic channel symbols provided at data source **20** in **FIG. 12**.

For the purpose of channel estimation, the transmitter shown in **FIG. 12** may transmit either two pilots mixed with the signals output from transformer **88**, or four pilots, wherein each antenna element **100** through **106** has its own pilot. If pilot signals are mixed with the first and second transformed data streams, inverse transformer **128** need not know the switching pattern of commutator **170**. If continuous pilots are added on each antenna element **100** through **106**, then inverse transform **128** will need to know the switching pattern and rate of switching in the transmitter of **FIG. 12**.

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With reference now to **FIG. 15**, there is depicted a high-level logic flowchart that shows the method and operation of the diversity receiver shown in **FIG. 14**. As illustrated, the process begins at block **370** and thereafter passes to block **372** wherein the process receives and down converts a received signal to produce a baseband received signal.

Next, the process despreads the baseband receive signal using a despreading code to produce received transformed signals, as illustrated at block **374**. The despreading code used in this step corresponds to the spreading code used in the transmitter for producing the first and second spread data streams with spreaders **92** (see **FIG. 12**). This despreading step may be performed by despreader **124** as shown in **FIG. 14**.

Next, the process performs an inverse transform operation on the received transform signal to produce an interleaved encoded signal, as depicted at block **376**. This inverse transform step may be performed by inverse transformer **128**, which is shown in **FIG. 14**. In a preferred embodiment, the inverse transformer is an inverse space-time transformer, such as shown and described with reference to **FIG. 4**.

Finally, the process deinterleaves and decodes the interleaved encoded signal to produce traffic channel data output. The de-interleaving and decoding processes are selected to deinterleave and decode the processes used in data source **20** (see **FIG. 12**).

And finally, referring to **FIG. 16**, there is depicted a diversity signal transmitter that is similar to the transmitter shown in **FIG. 12**. The transmitter shown in **FIG. 16** includes antenna switching to provide additional transmit diversity. In **FIG. 16**, antenna selector **140** is coupled to the outputs of hybrid matrix amplifier **180**. Within antenna selector **140** any input may be coupled to any antenna output, as directed by switching pattern generator **150**. The rate of antenna selection is determined by symbol clock **22** after it has been divided at divider **152** and further divided at divider **190**. Thus, antenna selection occurs at a

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rate equal to or slower than the switching in commutator **170**. The pattern output by switching pattern generator **150** may be the pattern shown in Table 1.

In order to show the present invention conceptually, antenna selectors **140** and **160** in **FIGs. 9, 10,** and **16** have been shown at the outputs of amplifiers **98** or at the output of hybrid matrix amplifier **180**. The switching performed by these antenna selector is preferably implemented on a baseband signal, such as the baseband signals following spreaders **92** and **94** in **FIGs. 9** and **10**, and the baseband signal following commutator **170** in **FIG. 16**.

The foregoing description of a preferred embodiment of the invention has been presented for the purpose of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise form disclosed. Modifications or variations are possible in light of the above teachings. The embodiment was chosen and described to provide the best illustration of the principles of the invention and its practical application, and to enable one of ordinary skill in the art to utilize the invention in various embodiments and with various modifications as are suited to the particular use contemplated. All such modifications and variations are within the scope of the invention as determined by the appended claims when interpreted in accordance with the breadth to which they are fairly, legally, and equitably entitled.

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Claims

What is claimed is:

1. A method for transmitting data from a transmitter to a receiver in a wireless communication system, wherein the transmitter uses an antenna array to transmit a signal having transmit diversity, the method comprising the steps of:

commutating groups of symbols of an input data stream to produce a plurality of commutated data streams;

transforming the plurality of commutated data streams to produce a plurality of transformed data streams;

spreading each transformed data stream with a selected one of a plurality of spreading codes to produce a plurality of antenna signals; and

transmitting each of the plurality of antenna signals using a selected one of a plurality of spaced apart antennas, wherein the plurality of spaced apart antennas are spaced apart to provide transmit diversity.

2. The method for transmitting data according to claim 1 wherein the step of commutating groups of symbols of an input data stream to produce a plurality of commutated data streams further includes:

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selecting an N-symbol group of an input data stream, where N is greater than or equal to 1;

outputting the N-symbol group at a first commutator output to produce a first commutated data stream;

selecting a second N-symbol group of the input data stream; and

outputting the second N-symbol group at a second commutator output to produce a second commutated data stream.

3. The method for transmitting data according to claim **1** wherein the step of transforming the plurality of commutated data streams to produce a plurality of transformed data streams further includes:

space-time coding a first commutated data stream to produce first and second transformed data streams; and

space-time coding a second commutated data stream to produce third and fourth transformed data streams.

4. The method for transmitting data according to claim **3** wherein the step of space-time coding a first commutated data stream to produce first and second transformed data streams further includes:

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in response to an input of a first commutated data stream having symbols $S_1S_1S_2S_2$, outputting, during a first period, symbols S_1S_1 from a first transform output, and outputting a negative complex conjugate of symbols S_2S_2 from a second transform output; and

outputting, during a second period, symbols S_2S_2 from the first transform output, and outputting a complex conjugate of symbols S_1S_1 from the second transform output.

5. The method for transmitting data according to claim **1** wherein the step of transmitting each of the plurality of antenna signals using a selected one of a plurality of spaced apart antennas further includes modulating, upconverting, amplifying, and transmitting each of the plurality of antenna signals using a selected one of a plurality of spaced apart antennas, wherein the plurality of spaced apart antennas are spaced apart to provide transmit diversity.

6. The method for transmitting data according to claim **1** wherein the step of transmitting each of the plurality of antenna signals using a selected one of a plurality of spaced apart antennas further includes selecting different antennas in the antenna array for transmitting each of the plurality of antenna signals.

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7. The method for transmitting data according to claim 6 wherein the step of periodically selecting different antennas in the antenna array for transmitting each of the plurality of antenna signals further includes periodically selecting different antennas in the antenna array for transmitting each of the plurality of antenna signals according to an antenna switching pattern that is synchronized with a symbol clock divided by an integer.

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8. A system for transmitting data from a transmitter to a receiver in a wireless communication system, wherein the transmitter uses an antenna array to transmit a signal having transmit diversity, the system comprising:

a commutator for commutating groups of symbols of an input data stream to produce a plurality of commutated data streams;

transformers for transforming the plurality of commutated data streams to produce a plurality of transformed data streams;

spreaders for spreading each transformed data stream with a selected one of a plurality of spreading codes to produce a plurality of antenna signals; and

transmitters for transmitting each of the plurality of antenna signals using a selected one of a plurality of spaced apart antennas, wherein the plurality of spaced apart antennas are spaced apart to provide transmit diversity.

9. The system for transmitting data according to claim 8 wherein the commutator for commutating groups of symbols of an input data stream to produce a plurality of commutated data streams further includes:

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means for selecting an N-symbol group of an input data stream, where N is greater than or equal to 1;

means for outputting the N-symbol group at a first commutator output to produce a first commutated data stream;

means for selecting a second N-symbol group of the input data stream; and

means for outputting the second N-symbol group at a second commutator output to produce a second commutated data stream.

10. The system for transmitting data according to claim **8** wherein the transformers for transforming the plurality of commutated data streams to produce a plurality of transformed data streams further includes:

a first space-time coder for space-time coding a first commutated data stream to produce first and second transformed data streams; and

a second space-time coder for space-time coding a second commutated data stream to produce third and fourth transformed data streams.

11. The system for transmitting data according to claim **10** wherein the first space-time coder for space-time coding a first commutated data stream to produce first and second transformed data streams further includes:

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means for outputting, during a first period, symbols S_1S_1 from a first transform output, and outputting a negative complex conjugate of symbols S_2S_2 from a second transform output in response to an input of a first commutated data stream having symbols $S_1S_1S_2S_2$; and

means for outputting, during a second period, symbols S_2S_2 from the first transform output, and outputting a complex conjugate of symbols S_1S_1 from the second transform output.

12. The system for transmitting data according to claim **8** wherein the transmitters for transmitting each of the plurality of antenna signals using a selected one of a plurality of spaced apart antennas further include means for modulating, upconverting, amplifying, and transmitting each of the plurality of antenna signals using a selected one of a plurality of spaced apart antennas, wherein the plurality of spaced apart antennas are spaced apart to provide transmit diversity.

13. The system for transmitting data according to claim **8** wherein the transmitters for transmitting each of the plurality of antenna signals using a selected one of a plurality of spaced apart antennas further include means for selecting different antennas in the antenna array for transmitting each of the plurality of antenna signals.

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14. The system for transmitting data according to claim **13** wherein the means for selecting different antennas in the antenna array for transmitting each of the plurality of antenna signals further includes means for periodically selecting different antennas in the antenna array for transmitting each of the plurality of antenna signals according to an antenna switching pattern that is synchronized with a symbol clock divided by an integer.

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15. A method for receiving data in a receiver in a wireless communication system, wherein the data has been transmitted from a transmitter using an antenna array to transmit a signal having transmit diversity, the method comprising the steps of:

receiving and down-converting a received signal to produce a baseband received signal;

despreading the baseband received signal using despreading codes that correspond to spreading codes used in the transmitter to produce antenna signals that are transmitted from antennas in the antenna array, wherein the despreading produces received transformed signals;

inverse transforming each received transformed signal to produce inverse transformer output signals;

de-commutating all inverse transformer output signals to produce a signal containing traffic channel data.

16. The method for receiving data according to claim **15** wherein the step of inverse transforming each received transformed signal to produce inverse transformer output signals further includes space-time decoding each received transformed signal to produce inverse transformer output signals.

17. The method for receiving data according to claim **15** wherein the step of de-commutating all inverse transformer output signals to produce a signal containing traffic channel data further includes:

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selecting and outputting a first group of symbols from a first inverse transformer output signals during a first period;

selecting and outputting a second group of symbols from a second inverse transformer output signals during a second period to produce a signal containing traffic channel data.

18. The method for receiving data according to claim **15** wherein the step of inverse transforming each received transformed signal to produce inverse transformer output signals further includes estimating two symbols using coherently combined channel gains to produce inverse transformer output signals.

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19. A system for receiving data in a receiver in a wireless communication system, wherein the data has been transmitted from a transmitter using an antenna array to transmit a signal having transmit diversity, the system comprising:

a receiver for receiving and down-converting a received signal to produce a baseband received signal;

despreaders for despreading the baseband received signal using despreading codes that correspond to spreading codes used in the transmitter to produce antenna signals that are transmitted from antennas in the antenna array, wherein the despreading produces received transformed signals;

inverse transformers for inverse transforming each received transformed signal to produce inverse transformer output signals;

a de-commutator for de-commutating all inverse transformer output signals to produce a signal containing traffic channel data.

20. The system for receiving data according to claim **19** wherein the inverse transformers for inverse transforming each received transformed signal to produce inverse transformer output signals further include space-time decoders for space-time decoding each received transformed signal to produce inverse transformer output signals.

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21. The system for receiving data according to claim **19** wherein the de-commutator for de-commutating all inverse transformer output signals to produce a signal containing traffic channel data further includes:

means for selecting and outputting a first group of symbols from a first inverse transformer output signals during a first period;

means for selecting and outputting a second group of symbols from a second inverse transformer output signals during a second period to produce a signal containing traffic channel data.

22. The system for receiving data according to claim **19** wherein the inverse transformers for inverse transforming each received transformed signal to produce inverse transformer output signals further include means for estimating two symbols using coherently combined channel gains to produce inverse transformer output signals.

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23. A method for transmitting data from a transmitter to a receiver in a wireless communication system, wherein the transmitter uses an antenna array to transmit a signal having transmit diversity, the method comprising the steps of:

transforming groups of symbols of an input data stream to produce a plurality of transformed data streams;

spreading each transformed data stream with a spreading code to produce a plurality of antenna signals;

selecting one of a plurality of spaced apart antennas from the antenna array for each one of the plurality of antenna signals, wherein the plurality of spaced apart antennas are spaced apart to provide transmit diversity; and

transmitting each of the plurality of antenna signals from the selected one of the plurality of spaced apart antennas.

24. The method for transmitting data according to claim **23** wherein the step of transforming groups of symbols of an input data stream to produce a plurality of transformed data streams further includes space-time coding a group of symbols of an input data stream to produce first and second transformed data streams.

25. The method for transmitting data according to claim **24** wherein the step of space-time coding a group of symbols of an input data stream to produce first and second transformed data streams further includes:

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in response to an input of a first commutated data stream having symbols S_1S_2, outputting, during a first period, symbol S_1 from a first transform output, and outputting a negative complex conjugate of symbol S_2 from a second transform output; and

outputting, during a second period, symbol S_2 from the first transform output, and outputting a complex conjugate of symbol S_1 from the second transform output, wherein the first and second transform outputs output first and second transformed data streams.

26. The method for transmitting data according to claim **23** wherein the step of spreading each transformed data stream with a spreading code to produce a plurality of antenna signals further includes spreading each transformed data stream with a same spreading code to produce a plurality of antenna signals.

27. The method for transmitting data according to claim **23** wherein the step of selecting one of a plurality of spaced apart antennas from the antenna array for each one of the plurality of antenna signals further includes periodically selecting N number of a plurality of X number of spaced apart antennas in the antenna array for each of N number of antenna signals, wherein N is an integer greater than or equal to 2, and X is an integer greater than or equal to 1.

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28. The method for transmitting data according to claim **23** wherein the step of transmitting each of the plurality of antenna signals from the selected one of the plurality of spaced apart antennas further includes modulating, upconverting, amplifying, and transmitting each of the plurality of antenna signals from the selected one of the plurality of spaced apart antennas, wherein the plurality of spaced apart antennas are spaced apart to provide transmit diversity.

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29. A system for transmitting data from a transmitter to a receiver in a wireless communication system, wherein the transmitter uses an antenna array to transmit a signal having transmit diversity, the system comprising:

a transformer for transforming groups of symbols of an input data stream to produce a plurality of transformed data streams;

spreaders for spreading each transformed data stream with a spreading code to produce a plurality of antenna signals;

means for selecting one of a plurality of spaced apart antennas from the antenna array for each one of the plurality of antenna signals, wherein the plurality of spaced apart antennas are spaced apart to provide transmit diversity; and

a transmitter for transmitting each of the plurality of antenna signals from the selected one of the plurality of spaced apart antennas.

30. The system for transmitting data according to claim **29** wherein the transformer for transforming groups of symbols of an input data stream to produce a plurality of transformed data streams further includes a space-time coder for space-time coding a group of symbols of an input data stream to produce first and second transformed data streams.

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31. The system for transmitting data according to claim **30** wherein the space-time coder for space-time coding a group of symbols of an input data stream to produce first and second transformed data streams further includes:

means for outputting, during a first period, symbol S_1 from a first transform output, and outputting a negative complex conjugate of symbol S_2 from a second transform output in response to an input of a first commutated data stream having symbols S_1S_2; and

means for outputting, during a second period, symbol S_2 from the first transform output, and outputting a complex conjugate of symbol S_1 from the second transform output, wherein the first and second transform outputs output first and second transformed data streams.

32. The system for transmitting data according to claim **29** wherein the spreaders for spreading each transformed data stream with a spreading code to produce a plurality of antenna signals further includes spreaders for spreading each transformed data stream with a same spreading code to produce a plurality of antenna signals.

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33. The system for transmitting data according to claim **29** wherein the means for selecting one of a plurality of spaced apart antennas from the antenna array for each one of the plurality of antenna signals further includes means for periodically selecting N number of a plurality of X number of spaced apart antennas in the antenna array for each of N number of antenna signals, wherein N is an integer greater than or equal to 2, and X is an integer greater than or equal to 1.

34. The system for transmitting data according to claim **29** wherein the transmitters for transmitting each of the plurality of antenna signals from the selected one of the plurality of spaced apart antennas further includes means for modulating, upconverting, amplifying, and transmitting each of the plurality of antenna signals from the selected one of the plurality of spaced apart antennas, wherein the plurality of spaced apart antennas are spaced apart to provide transmit diversity.

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35. A method for receiving data in a receiver in a wireless communication system, wherein the data has been transmitted from a transmitter using selected antennas in an antenna array for selected time periods to transmit a signal having different channels in response to the selected antennas in the selected time periods, the method comprising the steps of:

receiving and down-converting a received signal to produce a baseband received signal;

despreading the baseband received signal using a despreading code that corresponds to a spreading code used in the transmitter to produce a plurality of antenna signals that are transmitted from selected antennas in the antenna array, wherein the despreading produces received transformed signals; and

in response to the channel determined by the selected antennas in the selected time period, inverse transforming each received transformed signal to produce inverse transformer output signals.

36. The method for receiving data according to claim **35** wherein the step of inverse transforming each received transformed signal to produce inverse transformer output signals further includes space-time decoding each received transformed signal to produce inverse transformer output signals.

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37. A system for receiving data in a receiver in a wireless communication system, wherein the data has been transmitted from a transmitter using selected antennas in an antenna array for selected time periods to transmit a signal having different channels in response to the selected antennas in the selected time periods, the system comprising:

a receiver for receiving and down-converting a received signal to produce a baseband received signal;

a despreader for despreading the baseband received signal using a despreading code that corresponds to a spreading code used in the transmitter to produce a plurality of antenna signals that are transmitted from selected antennas in the antenna array, wherein the despreading produces received transformed signals; and

an inverse transformer for inverse transforming each received transformed signal to produce inverse transformer output signals in response to the channel determined by the selected antennas in the selected time period.

38. The system for receiving data according to claim **37** wherein the inverse transformer for inverse transforming each received transformed signal to produce inverse transformer output signals further includes a space-time decoder for space-time decoding each received transformed signal to produce inverse transformer output signals.

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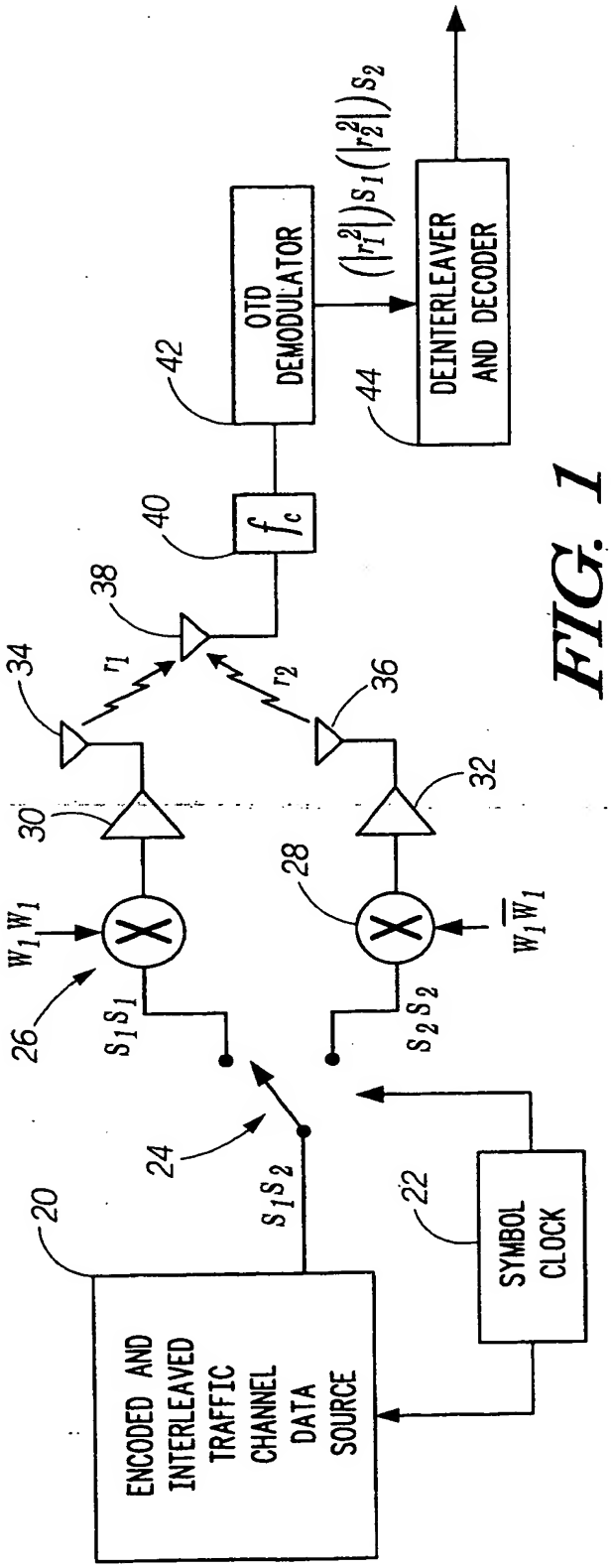

FIG. 1

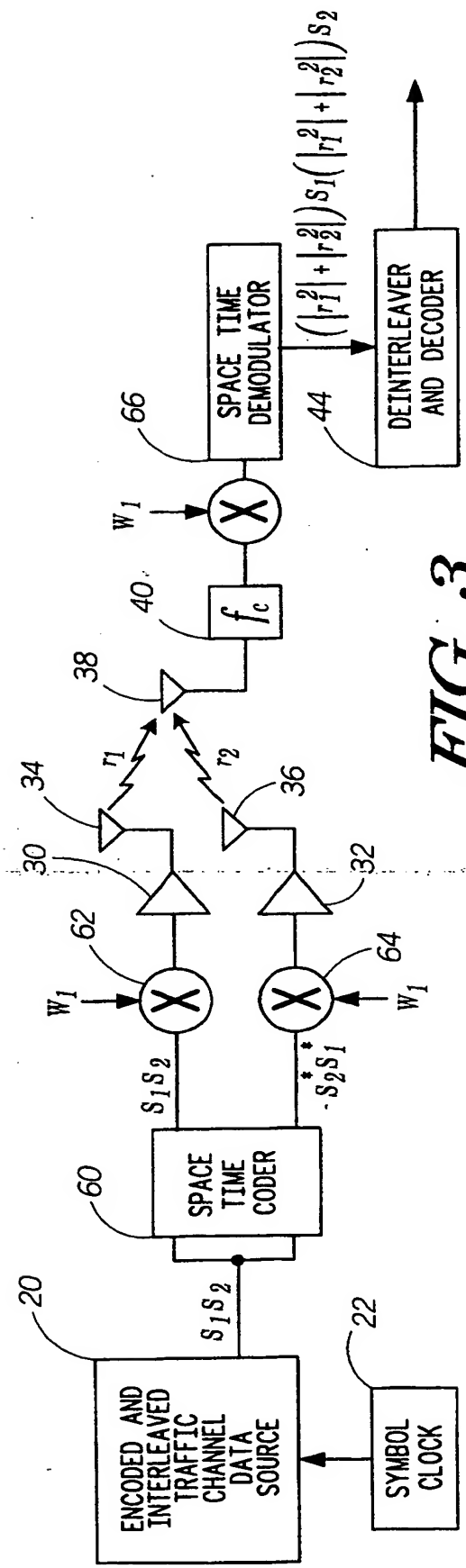

FIG. 3

BNSDOCID: <WO___0051265A1_I_>

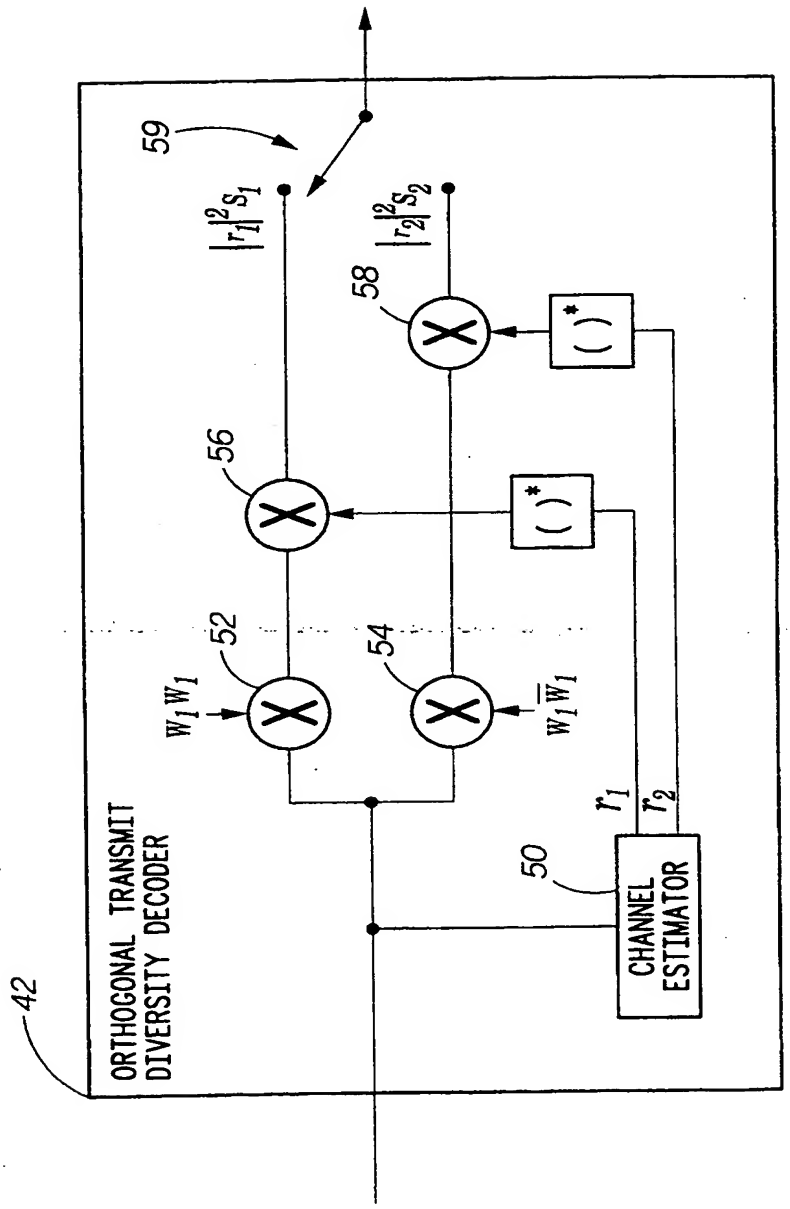

FIG. 2

BNSDOCID: <WO___0051265A1_I_>

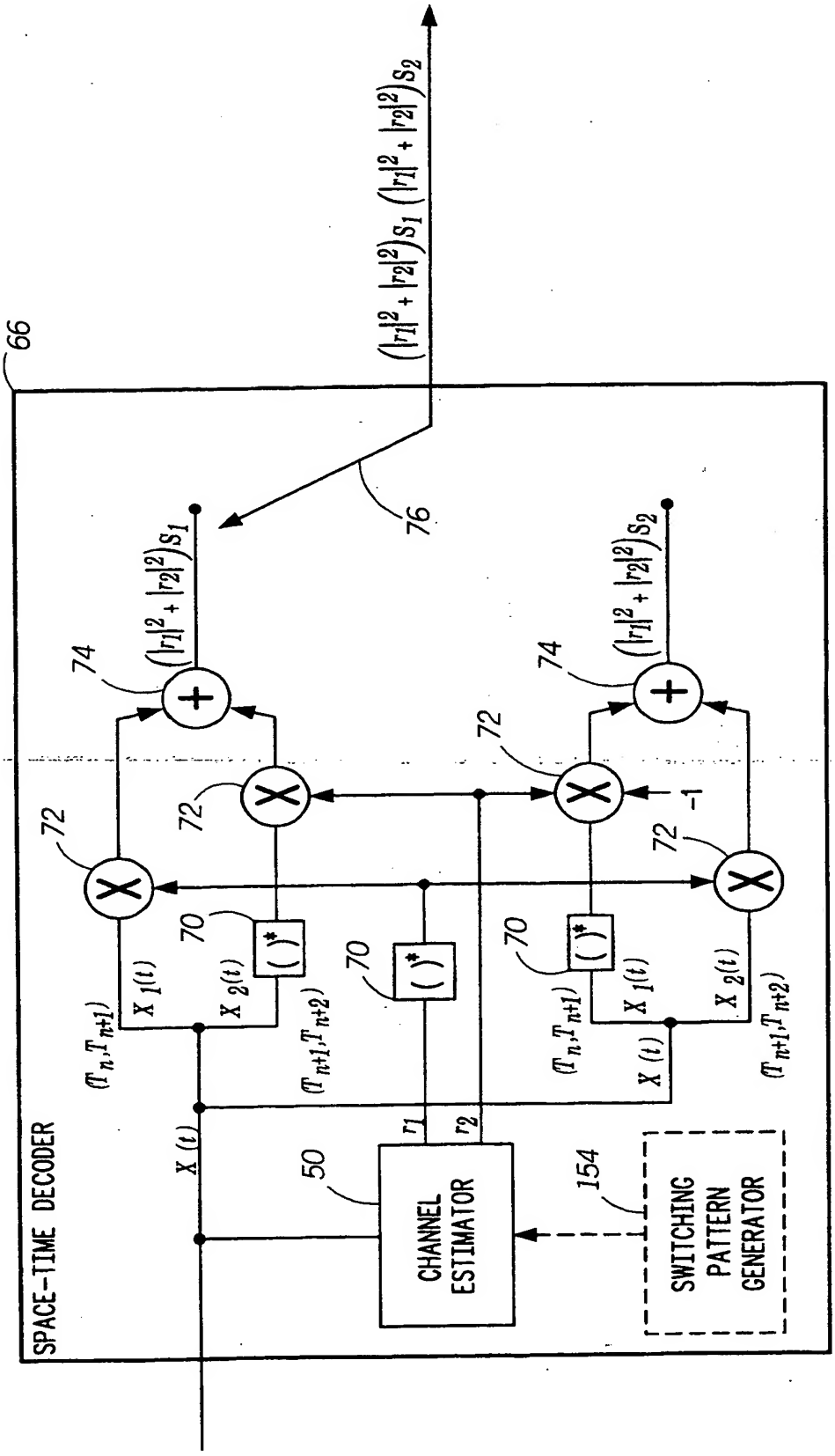

FIG. 4

3NSDOCID: <WO___0051265A1_I_>

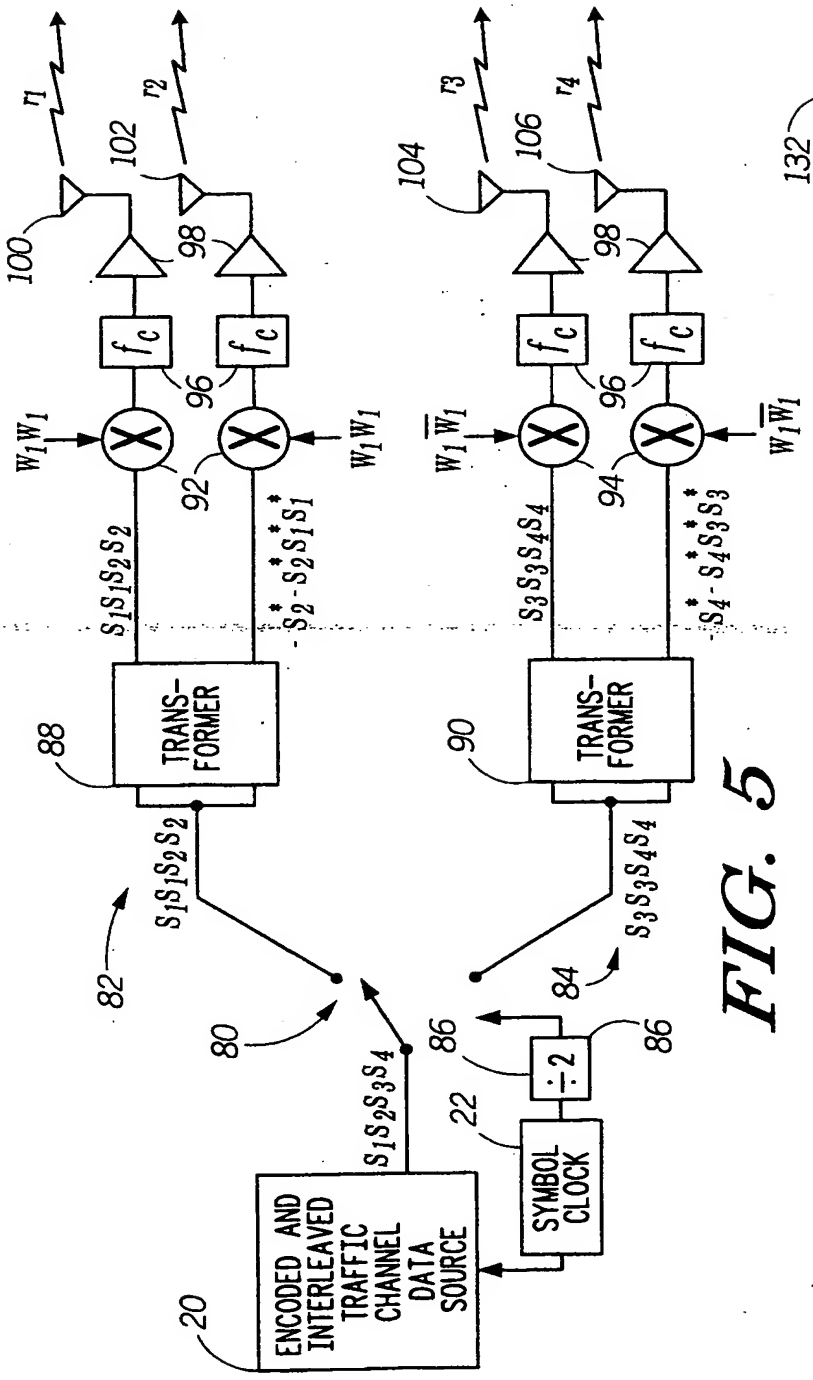

FIG. 5

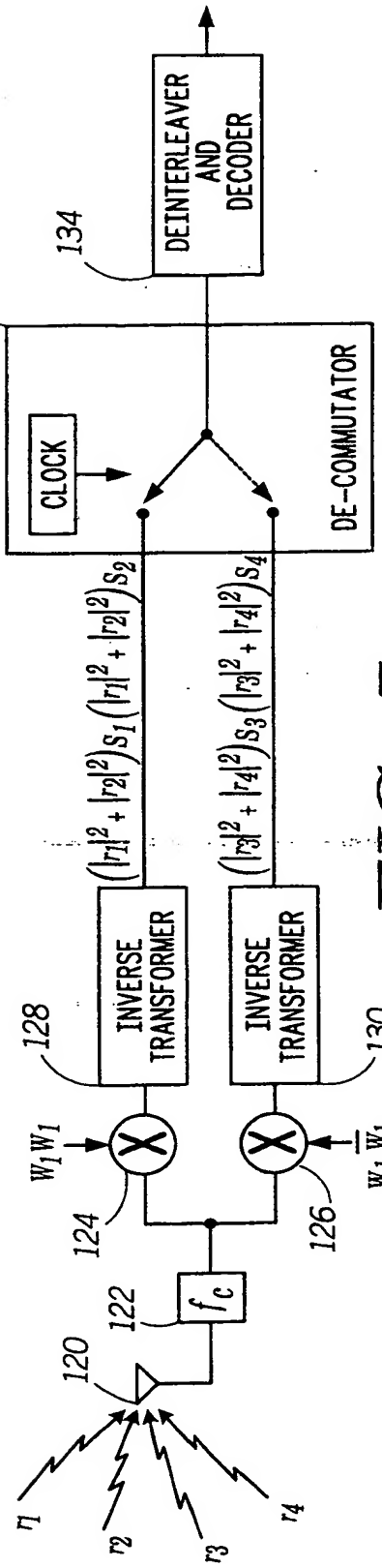

FIG. 7

BNSDOCID: <WO___0051265A1_I_>

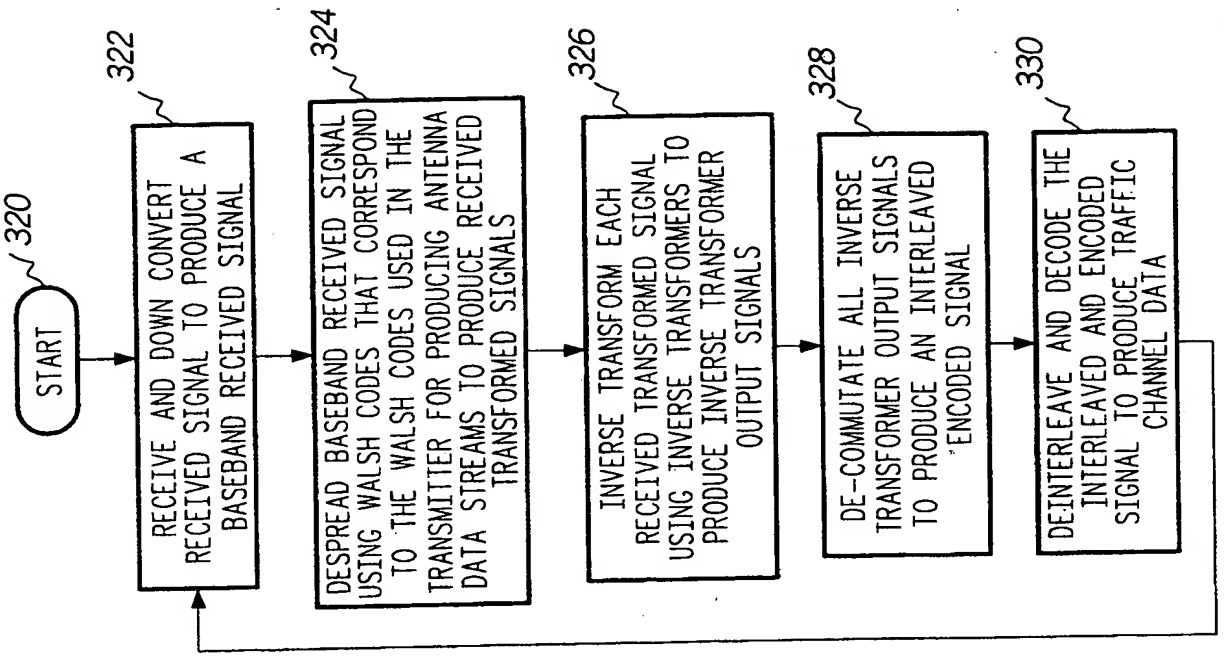

FIG. 8

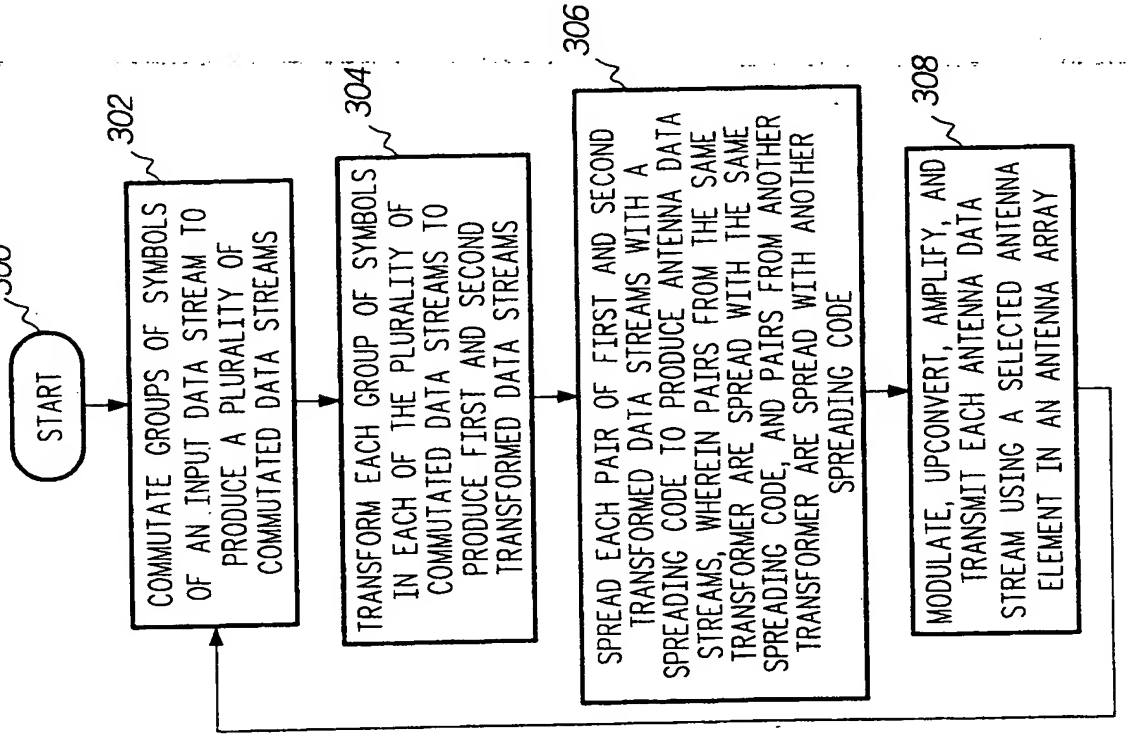

FIG. 6

BNSDOCID: <WO___0051265A1_I_>

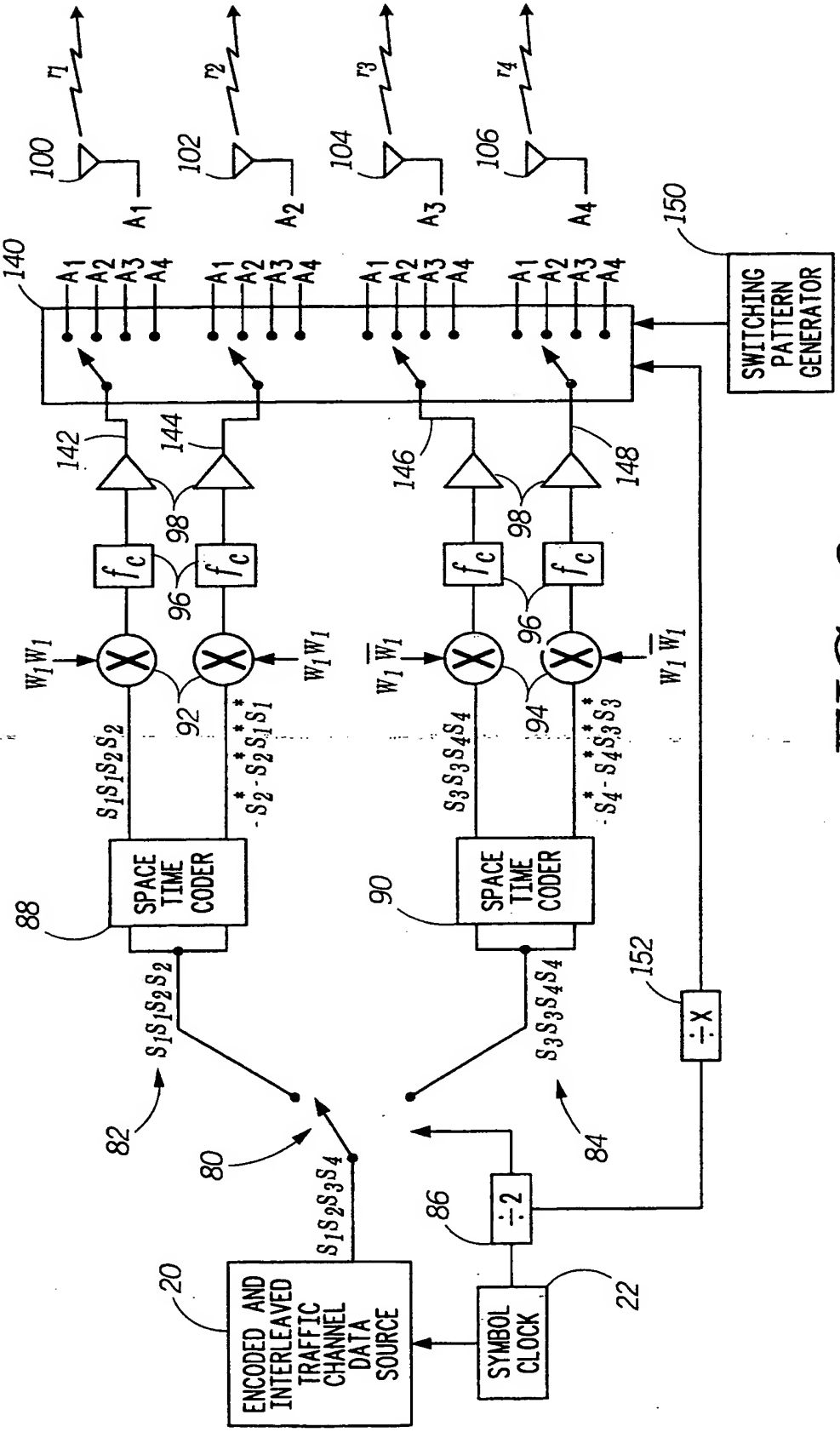

FIG. 9

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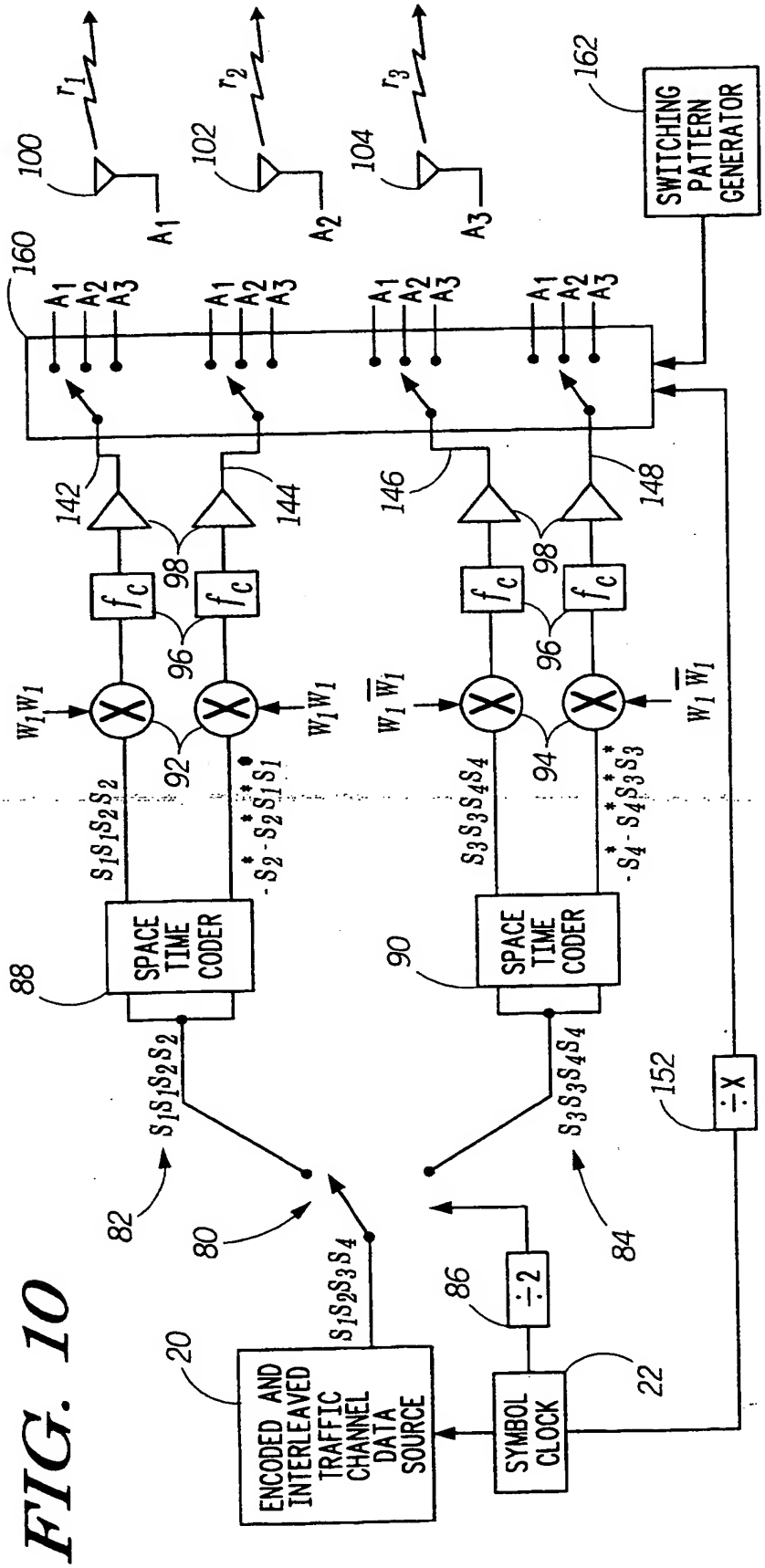

FIG. 10

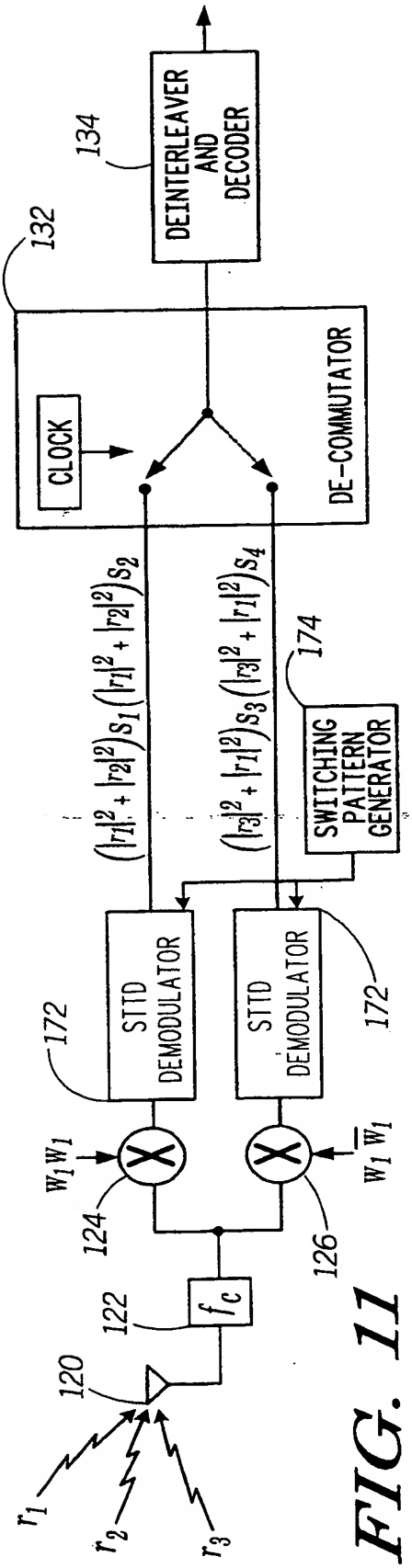

FIG. 11

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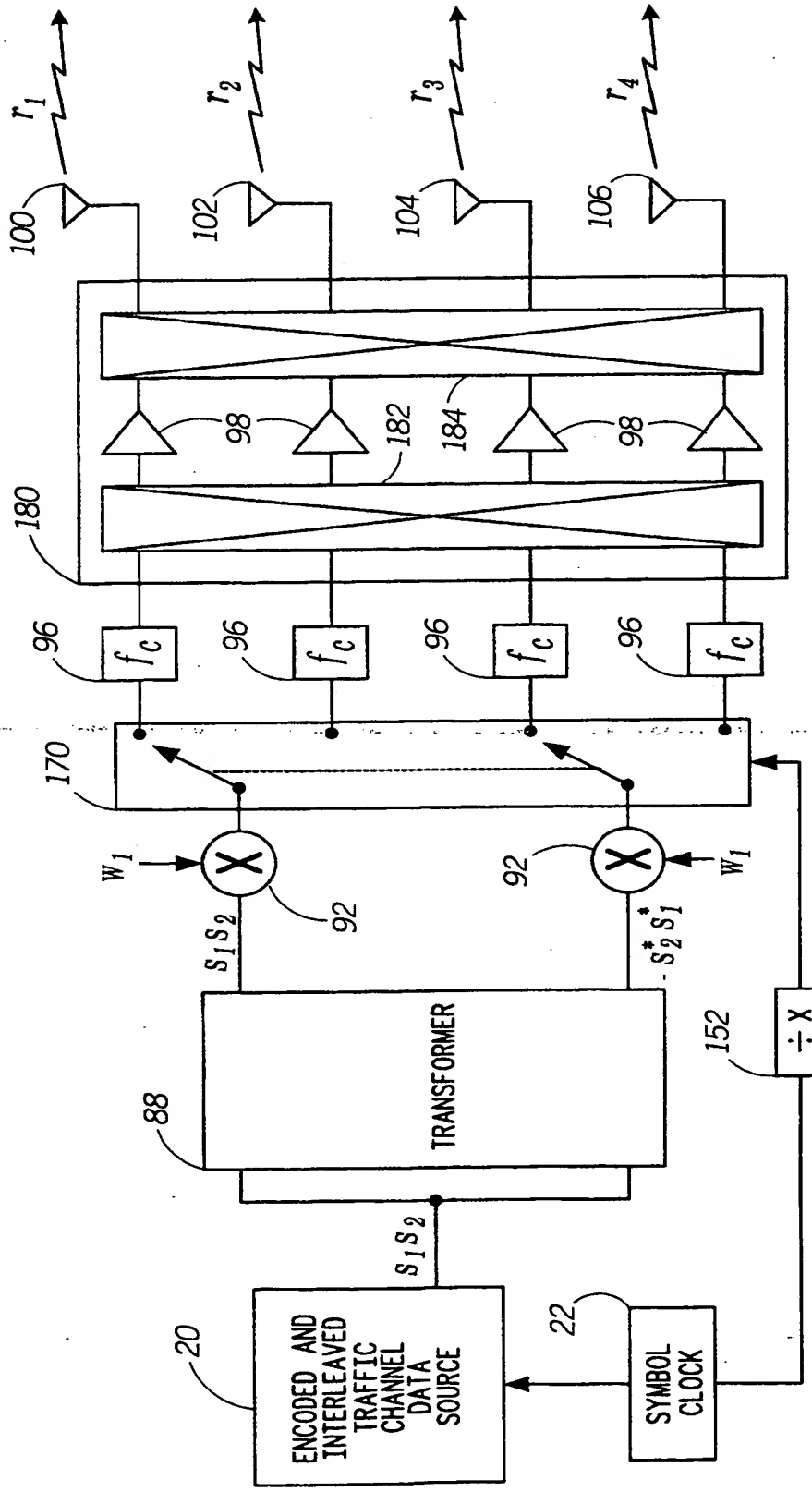

FIG. 12

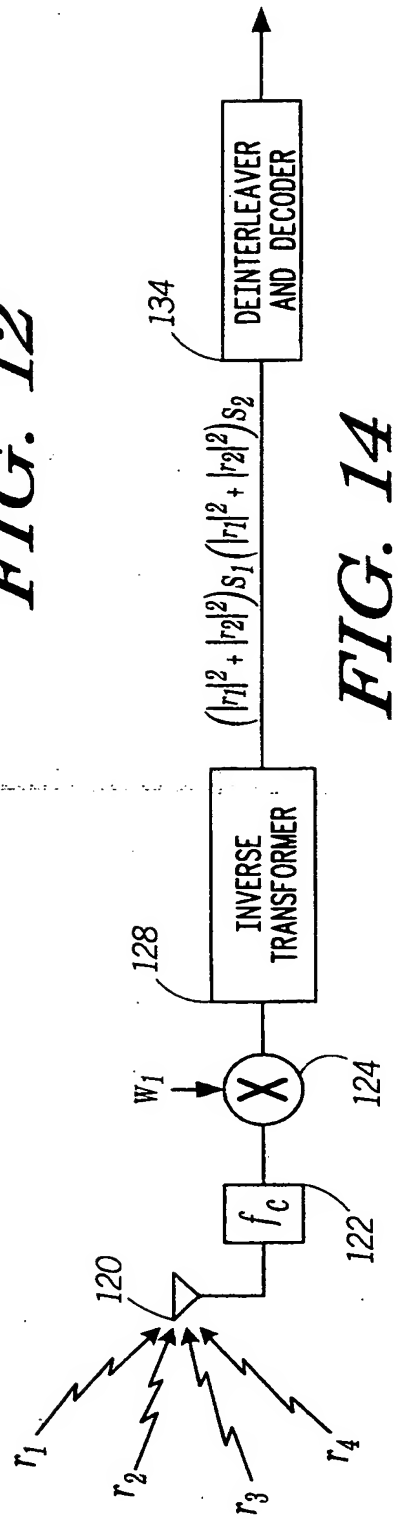

FIG. 14

BNSDOCID: <WO___0051265A1_I_>

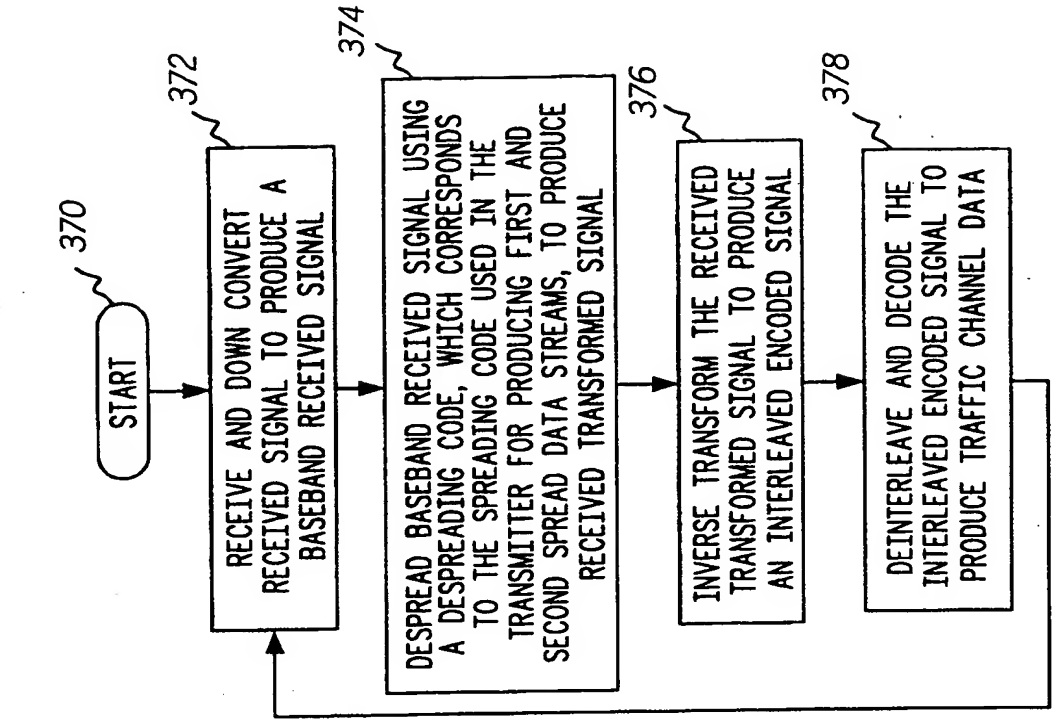

FIG. 15

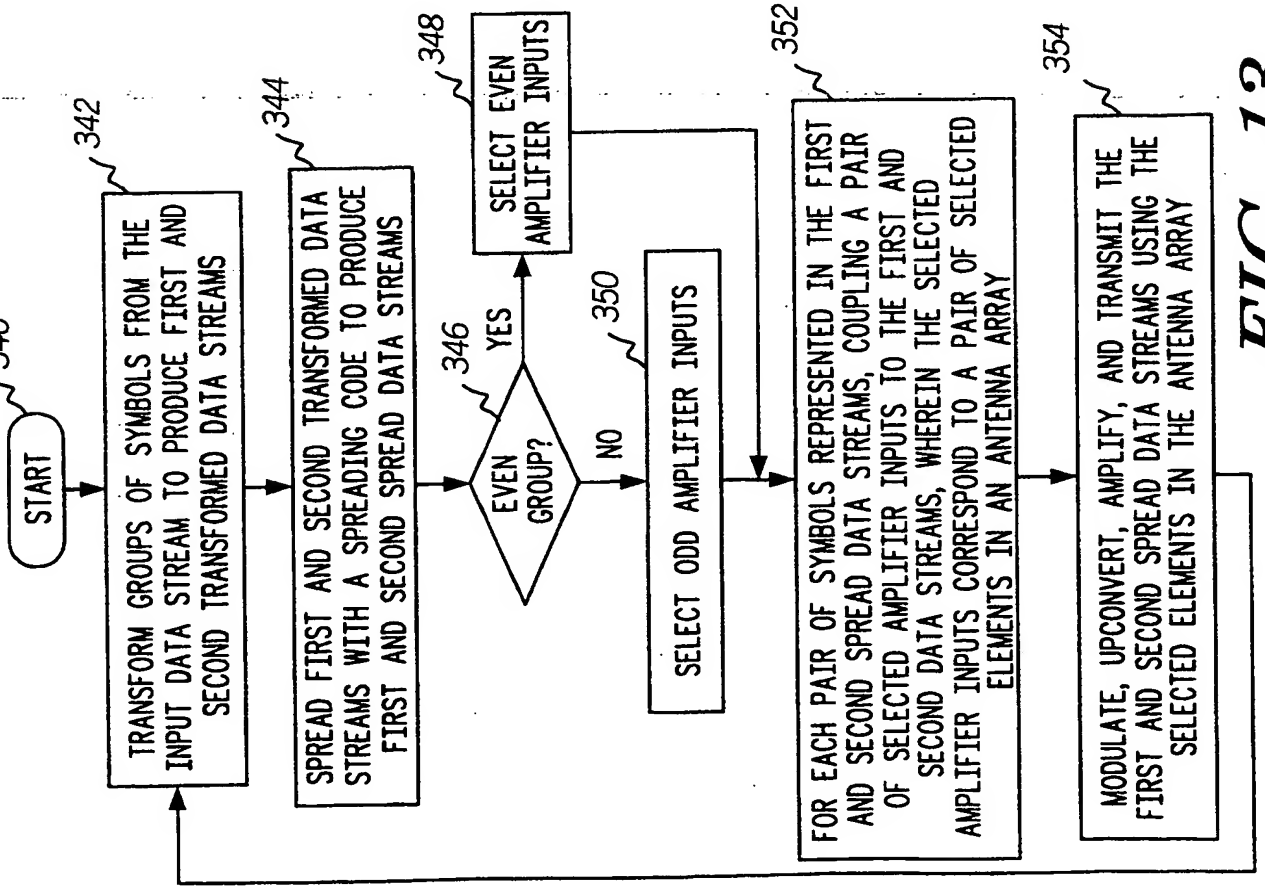

FIG. 13

BNSDOCID: <WO___0051265A1_I_>

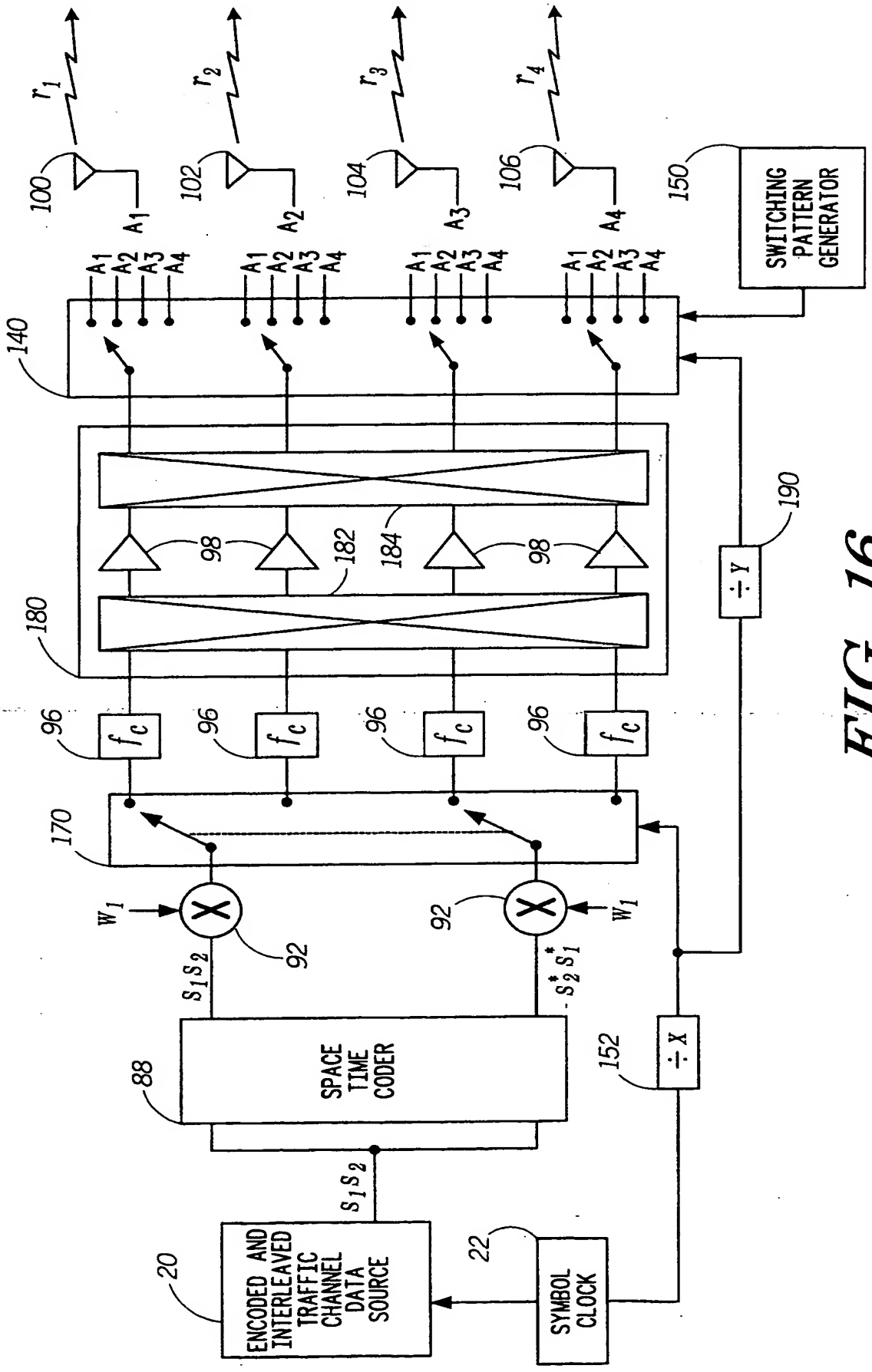

FIG. 16

BNSDOCID: <WO___0051265A1_I_>

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US00/02958

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : H04B 7/06
US CL : 370/342, 441, 479
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 370/342, 441, 479

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
BRS (east)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, E	US 6,038,263 A (KOTZIN et al) 14 March 2000, Entire document.	1-38
X,P	EP 0 929161 A2 (RAMESH NALLEPILLI) 14 July 1999, abstract, col. 3, lines 38-52	1

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents
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"E" earlier document published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 APRIL 2000	21 APR 2000
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer AHMED ELALLAM Telephone No. (703) 305-3900

Form PCT/ISA/210 (second sheet) (July 1998)*

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